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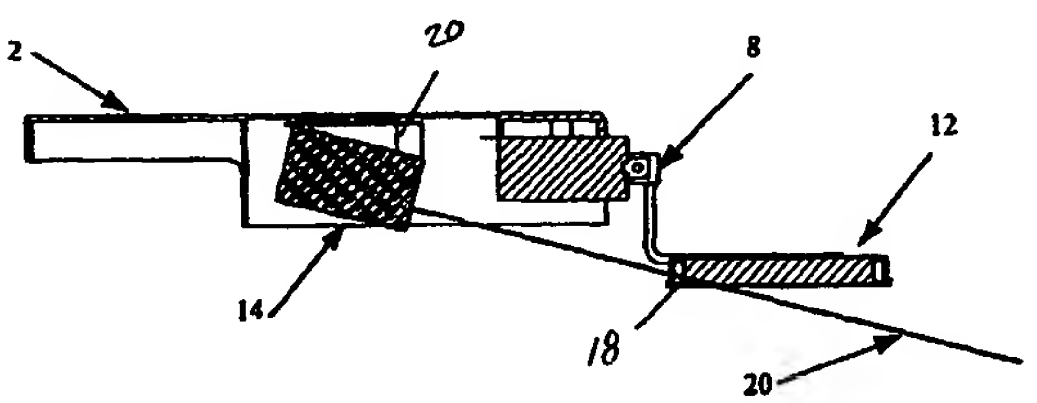
(54) Title: ROBOT MOUNTED BARCODE READER



(57) Abstract: A robotic arm-mounted laser barcode reader is provided. The robotic arm-mounted laser barcode reader may be used in the field of sample analysis to increase the rate with which sample carriers such as microtitre plates may be interfaced with an automated system. The robotic arm-mounted laser barcode reader can read a bar code label affixed to a sample carrier immediately when the robotic arm grabs and manipulates a sample carrier, eliminating the step of presenting the sample carrier to a separate bar code reader to ensure proper tracking and/or inventorying of the sample carrier. The robotic arm-mounted laser barcode reader may also be used in other automated apparatuses that require tracking and/or inventorying.

WO 01/56753 A1

ROBOT MOUNTED BARCODE READER

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to an apparatus and method for identifying objects in automated platform.

Description of the Related Art

In the field of molecular biology, the process of sequencing nucleic acids has become significant as more and more diseases are linked to genetic abnormalities. The process of identifying genes and their corresponding proteins for potential therapeutic applications is well known.

Other types of molecular biology procedures are also important for therapeutic and research purposes including DNA restriction mapping, DNA probe generation, replication, DNA sample processing, and cycle sequencing. Generally, these procedures involve a substantial number of steps including, without limitation, automated liquid handling, robotic movement of the samples, pipetting of small amounts of many different reagents into a sample, and heating the samples within a given temperature range. These protocols includes a lengthy series of steps which must be performed in the correct order with absolute precision. Further, such assays are often done on multiple samples that require the manipulation of samples in sample carriers in a uniform fashion.

For instance, during clinical analysis of blood chemistry, various reagents and catalysts are mixed with blood samples in given amounts and in particular sequences. This analysis can yield the level of HDL cholesterol, LDL cholesterol, lipids, etc. present in the blood. By having multiple samples in a sample carrier, several samples may be analyzed at any give time. Similarly, in the area of new drug discovery, it is desirable to investigate numerous candidates for therapeutic agents. Given the great number of potential candidates, automated testing is desirable.

Because of the expense of the equipment required to perform these protocols accurately, increasing the throughput of the equipment performing these protocols becomes important for laboratories such as microbiology laboratories. It is desirable to increase the

rate at which these protocols are performed while retaining, or even increasing, the quality of performance of the protocols. Automation is one method by which the rate of performing the protocols may be increased. By increasing the rate at which these protocols are performed, the protocols may be performed at a reduced price.

Regardless of the type of experiment to be performed, sample carriers are generally employed so that more than one sample may be processed at any given time. For example, microtitre plates are generally utilized in these sample analysis protocols. Microtitre plates are plastic plates containing uniformly-spaced cavities for holding various liquids. Generally, these commercially available microtitre plates contain eight rows of twelve microwells for an industry-standard ninety-six microtitre plate, or sixteen rows of twenty-four microwells for an industry-standard three hundred eighty-four microtitre plate. Other sizes are also commercially available.

It is generally known to perform a protocol with automation as follows. Multiple microtitre plates are stacked in one location. A transfer mechanism transfers one the of the microtitre plates to a robotic arm. The robotic arm transports the microtitre plate to the desired station, e.g. a pipetting station. The robotic arm then takes the microtitre plate to the next station, and so on until the desired protocol has been performed on that microtitre plate.

Throughout the process, each of the microtitre plates must be tracked and inventoried with precision so that the contents of each of the microtitre plates is always known and the manipulations can all be done at the right times. It has become common recently to use laser bar coding to keep track of each of the microtitre plates. Generally a barcode label is attached to each microtitre plate and the robotic automation platform will utilize a stand-alone barcode reader. The robotic arm must grip the microtitre plate with the barcode applied, carry the plate to the proper position, and present the label to the barcode reader station. After the barcode reader has read the barcode, the robotic arm may then carry the microtitre plate to wherever the next step is scheduled to take place. This operation is inefficient in that it requires transport time for the robotic arm movements to and from the barcode reading station.

Thus, despite years of effort, the method of tracking and manipulating sample carriers such as microtitre plates or other items to perform various protocols continues to be slower and more expensive than would be desired.

The present invention is directed to overcoming, or at least reducing the effects of, one or more of the problems set forth above.

SUMMARY OF THE INVENTION

In accordance with an aspect of the present invention, a robotic arm mounted object identification system is provided.

In accordance with another aspect of the present invention, there is provided a barcode reader directly a robotic arm to reduce the time in an automated process. In some aspects the integrated barcode reader includes a robotic arm with the barcode reader mounted thereto to read barcode graphics applied to an object as the robotic arm moves from one location to another.

In one aspect of the present invention the robotic arm comprises a body attached to an automated apparatus and a laser barcode reader attached to the robotic arm. In this embodiment the robotic arm may be adapted to manipulate a microtitre plate or other sample carrier. The robotic arm may include a plurality of end effector grippers to grip the sample carriers. In one embodiment the end effector grippers offset the sample carrier a predetermined distance from the robotic arm such that a surface of the microtitre plate faces the laser barcode reader.

In one embodiment a robotic arm including a body having first and second ends is described. In this embodiment the first end is attached to an automated apparatus and the second end is attached to a microtitre plate holder with a laser barcode reader mounted to the body.

In another embodiment an automated apparatus for manipulating microtitre plates includes a robotic arm mounted to the automated apparatus, a laser barcode reader mounted to the robotic arm, and a microtitre plate holder attached to the robotic arm. In this embodiment a microtitre plate surface with a barcode label affixed thereto is exposed to the laser mounted barcode reader. The microtitre plate holder may be adapted to grip two

opposing surfaces of the microtitre plate with a plurality of generally L-shaped end effector grippers. The microtitre plate holder is arranged such that there is a clear line-of-sight between the laser barcode reader and the microtitre plate holder. The clear line-of-sight may be created by positioning the laser barcode reader at a predetermined angle and offsetting the microtitre plate a predetermined distance from the robotic arm with the microtitre plate holder.

In another aspect of the present invention an automated apparatus for manipulating sample carriers only includes mounting a laser barcode reader to a robotic arm. In this aspect the sample carriers may be microtitre plates and the robotic arm may include a body with first and second ends, the first end being attached to the automated apparatus; a microtitre plate holder connected to the second end; and a support mount attached to the body for mounting the laser barcode reader to the robotic arm. The microtitre holder may include a pair of end effector grippers offset from the body by a predetermined clearance dimension, and the laser barcode reader may be mounted to the robotic arm such that a clear line-of-site exists between the laser barcode reader and the microtitre plates.

In another aspect of the invention a method of tracking and/or inventorying sample carriers is described. The method may include the steps of applying a barcode label to the sample carrier and reading the barcode label with a robotic arm-mounted laser barcode reader. The sample carriers in this aspect of the invention may be microtitre plates and the robotic arm may include a body with first and second ends, the first end being attached to an automated apparatus; a sample carrier holder connected to the second end; and a support mount attached to the body for mounting the laser barcode reader to the robotic arm. The method may also include receiving data from the laser barcode reader by a computer for monitoring, tracking, and/or other purposes.

In another aspect of the present invention an alternative reading device such as a radio frequency detector reads a radio frequency tag on the object in place of the laser barcode reader and barcode label

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and aspects of the invention will become further apparent upon reading the following detailed description and upon reference to the drawings in which:

Figure 1 is a perspective view of one embodiment of a robot mounted barcode reader in accordance with the present.

Figure 2 is a second perspective view of the embodiment shown in Figure 1.

Figure 3 is a side cross-sectional view of the embodiment shown in Figure 1.

Figure 4 is a perspective view of a microtitre plate.

Figure 5 is a third perspective view of the embodiment shown in Figure 1.

Figure 6 is a perspective view of the embodiment shown in Figure 1 integrated with a processing system.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, that will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

In one embodiment the invention relates to an apparatus and a method to increase the throughput of manipulating microtitre plates when performing various protocols. The invention increases throughput by eliminating the step of presenting each sample carrier to a separate barcode reading machine between manipulation processes.

Figure 1 shows one embodiment of a robotic arm in accordance with the present invention. Robotic arm includes a body, a first end, and a second end. First end is adapted to attach to a standard commercially available robot such as the one shown in Figure 6.

Robotics to use with arm ay be purchased from Equipe Technologies or other robotics sources. It is within the skilled artisan's ordinary ability with the benefit of this disclosure to adapt robotic arm to any commercially available robotics provider. Second end f robotic arm is attached to a microtitre plate holder, for example a set of end-effector grippers. End effector grippers may be configured in the generally L-shape shown in the figures and are commercially available as shown in the figures. End effector grippers are designed to open and close as programmed by the robotic apparatus to carry and release a sample carrier such as microtitre plate. End effector grippers may include rubber pads to facilitate surface contact against sides and of microtitre plate.

Referring to Figure 2, a perspective view opposite the view shown in Figure 1 is shown. Figure 2 shows that a laser barcode reader is mounted underneath robotic arm in a recess. Barcode reader is small enough to easily fit within recess. In one embodiment the dimensions of barcode reader measure no more then three inches by four inches by two inches. Small laser barcode readers that can readily be disposed in recess of robotic arm are commercially available from Microscan or other barcode reader manufacturers. Microscan model MS-310, for example, may be mounted to robotic arm within recess. Alternatively, other object identification systems may be used including, but not limited to, CCD barcode readers, 2-D barcode readers, and magstripe readers. The invention is thus not limited to the laser barcode reader disclosed, any identification system known to those of skill in the art with the benefit of this disclosure may be used. In each of the alternative identification systems, the associated tags and graphics to be detected and/or read will be incorporated with the object to be identified. It is within the ordinary skill of one in the art with the benefit of this disclosure to find and purchase such systems and tags.

Laser barcode reader is mounted to robotic arm by support bracket. Support bracket is shown in cross-section in Figure 3 and is arranged to mount laser barcode reader at an angle creating a clear line of site between the laser barcode reader and a side of microtitre plate. A laser line projection is shown in Figures 1-3 illustrating the clear line of sight that is necessary between the laser barcode reader and surface of microtitre plate. In the alternative, barcode reader may not be mounted in a position with a constantly clear line of site to

microtitre plate. In this alternative, robotic arm may be manipulated to a position other that the position at which it will pick up microtitre plate to create a clear line of site to read the barcode.

Careful mounting of barcode reader to robotic arm may be important for accurate barcode readings. Typically barcode reading lasers will only register barcodes when directed at a barcode label from specific distances and ranges of angles. It is within the ordinary skill of one in the art with the benefit of this disclosure to determine the distance and angle requirements of a barcode reader and mount barcode reader on robotic arm in compliance with the barcode reader's limitations.

For example, according to one embodiment as shown in the figures, the distance and angle between barcode reader and a barcode label (shown in Figure 5) are ensured to be within the readable limits of the barcode reader by adjusting three components. First, barcode label is positioned properly at point of microtitre plate (shown in Figure 4). End effector grippers hold microtitre plate by closing on opposing edges. Barcode label must be applied to plate surface facing barcode reader. The second component is the microtitre plate position relative to robotic arm. As mentioned above, in order for barcode label to be visible to barcode reader, a clear line of sight is required. End effector grippers hold microtitre plate by edges distance below robotic arm to provide an unobstructed path from the reader to the label. In the embodiment shown in the figures, the L-shape configuration of end effector grippers provides the clearance necessary between a robotic arm and barcode label applied to surface. Third, the position of microtitre plate in end effector grippers and the mounting position of barcode reader on robotic arm determines the line-of-sight distance and reading angles required for registering the barcode. Again, it will be understood by one of skill in the art with the benefit of this disclosure that other barcode readers other than laser barcode reader may be used. It will also be understood by one of skill in the art with the benefit of this disclosure that barcodes and other detectable labels and tags may include other than applied label, including, but not limited to, ink jet applied directly to the object, thermal transfer printing directly on the object, bar codes molded into the object, and RF tags attached to or molded into the object.

Robotic arm may have a radio frequency (RF) terminal mounted thereto for identifying information about the object being manipulated. RF tags would thus be attached and/or embedded into microtitre plate or other objects to be detected and identified by the RF terminal. Other object identification systems known in that art may also be used in an automated apparatus for objects such as sample carriers.

Referring now to Figure 6, a automated apparatus incorporating robotic arm is shown for performing various sample analysis protocols. Five stackers are shown, although any number of stackers required for a particular protocol can be used, as may a conveyor in place of the stackers. Further, in many instances, it is desirable to have this entire work area enclosed. All microtitre plates are labeled with a barcode label and computer cataloged and/or inventoried prior to use. After stacker or the conveyor (not shown) prepares a microtitre plate for presentation, end effector grippers on robotic arm will be directed to that stacker or conveyor and lift the microtitre plate from stacker table. At that point, bar code reader (not visible in Figure 6) immediately reads barcode label (also not shown in Figure 6) and relays the information contained in the bar code to a computer for tracking and cataloging/inventory purposes. Robotic arm is attached to robot and can carry the microtitre plate to a pipetting station to dispense small amounts of liquid. Robot arm can also carry the microtitre plate to hotel. Hotel may be a heating station. For instance, in some sample analyses, it is required to combine reagents in a controlled environment at a particular temperature which is above ambient temperature. In these instances, hotel acts as an oven in which this reaction may occur. Each of these operations can be done with automatic tracking as barcode reader is mounted directly on robotic arm and reads barcode label anytime a microtitre plate is moved by the robot arm.

Hotel may possess light detectors. In this way, if clear microtitre plates are utilized, light may shine one side of the microtitre plate in the hotel. Detectors may reside on the hotel positioned on the other side of the microtitre plate and these detectors determine, for example, the color of the sample in each cavity of the microtitre plates.

Robot arm may carry the microtitre plate to the various resting stations, in fact any number of procedures could be performed in this fashion. Advantageously, a barcode

reading station which would typically be placed on table to track the microtitre plates as the procedures are performed, is no longer necessary. Significant time savings is achieved as there is no need to pause between procedures to present the microtitre plate to a barcode reading station. There may also be a plate washing cell (not shown) on table. Any number of steps in a biological protocol may be performed. Once one particular microtitre plate has had all the steps performed as required by protocol, robotic arm may return the microtitre plate to stacker or conveyor and an operator (not shown) may remove the completed microtitre plates to another area for post-processing as required. The robotic arm mounted barcode reader will have recorded all the tracking information throughout the processing steps without ever slowing down to present each microtitre plate to a barcode reading station.

Robotic arm mounted barcode reader may also be used in any other automated procedure in which reading bar codes and/or identifying and tracking objects is necessary, the invention is not limited to the particular use described above for manipulating sample carriers.

The appended claims are intended to cover all such modifications and variations not limited to the specific embodiments which occur to one of ordinary skill in the art; the claims are not limited to the specific embodiments earlier described.

Although various embodiments have been shown and described, the invention is not so limited and will be understood to include all such modifications and variations as would be apparent to one skilled in the art.

CLAIMS:

1. A robotic arm comprising a body attached to an automated apparatus and an object identifying system attached to the robotic arm

2. The robotic arm of claim 1 wherein the object identifying system is a laser barcode reader.

3. The robotic arm of claim 1 wherein the object identifying system is a CCD barcode reader.

4. The robotic arm of claim 1 wherein the object identifying system is an RF terminal.

5. The robotic arm of claim 1 wherein the object identifying system is a 2-D barcode reader.

6. The robotic arm of claim 1 wherein the robotic arm is adapted to manipulate a sample carrier.

7. The robotic arm of claim 6 further comprising a plurality of end effector grippers to grip the sample carrier.

8. The robotic arm of claim 7 wherein the end effector grippers offset the sample carrier a predetermined distance from the robotic arm.

9. The robotic arm of claim 8 wherein a surface of the sample carrier faces an unobstructed path to the object identifying system.

10. A robotic arm apparatus comprising:

a body with first and second ends, wherein the first end is attached to an automated apparatus and the second end is attached to a microtitre plate holder; and

an object identifying system mounted to the body.

11. The apparatus of claim 10 wherein the object identifying system is a barcode reader.

12. An automated apparatus for manipulating microtitre plates comprising:

a robotic arm mounted to the automated apparatus;

a barcode reader mounted to the robotic arm; and

a microtitre plate holder attached to the robotic arm.

13. The apparatus of claim 12 wherein a microtitre plate surface with a barcode thereon is exposed to the laser mounted barcode reader.

14. The apparatus of claim 12 wherein the microtitre plate holder is adapted to grip two opposing surfaces of the microtitre plate.

15. The apparatus of claim 12 wherein the microtitre plate holder is a plurality of generally L-shaped end effector grippers.

16. The apparatus of claim 12 further comprising a clear line-of-sight between the barcode reader and the microtitre plate holder.

17. The apparatus of claim 16 wherein the clear line of sight is created by positioning the barcode reader at a predetermined angle and offsetting the microtitre plate a predetermined distance from the robotic arm with the microtitre plate holder.

18. In an automated apparatus for manipulating sample carriers, the improvement comprising mounting a barcode reader to a robotic arm.

19. The apparatus of claim 18 wherein the barcode reader is a laser barcode reader.

20. The apparatus of claim 18 wherein the barcode reader is a CCD barcode reader.

21. The apparatus of claim 18 wherein the sample carriers are microtitre plates.

22. The apparatus of claim 18, wherein the robotic arm comprises:

a body with first and second ends, the first end being attached to the automated apparatus;

a microtitre plate holder connected to the second end; and

a support mount attached to the body for mounting the barcode reader to the robotic arm.

23. The apparatus of claim 22, wherein the microtitre holder comprises a pair of end effector grippers offset from the body by a predetermined clearance dimension.

24. The apparatus of claim 18 wherein the barcode reader is mounted to the robotic arm such that a clear line of site exists between the barcode reader and the microtitre plates.

25. A method of tracking and/or inventorying objects comprising:

providing an object with an identification tag; and

identifying the tag with a robotic arm-mounted tag reader.

26. A method of tracking and/or inventorying sample carriers comprising:

applying a barcode to the sample carrier; and

reading the barcode with a robotic arm-mounted barcode reader.

27. The method of claim 26 wherein the sample carriers are microtitre plates.

28. The method of claim 26 wherein the robotic arm comprises:

a body with first and second ends, the first end being attached to an automated apparatus;

a sample carrier holder connected to the second end; and

a support mount attached to the body for mounting the barcode reader to the robotic arm.

29. The method of claim 26 further comprising receiving data from the barcode reader by a computer.

30. The method of claim 26 wherein the bar code reader is a laser barcode reader.

31. In an automated apparatus for manipulating objects, the improvement comprising mounting an object identifying system to a robotic arm.

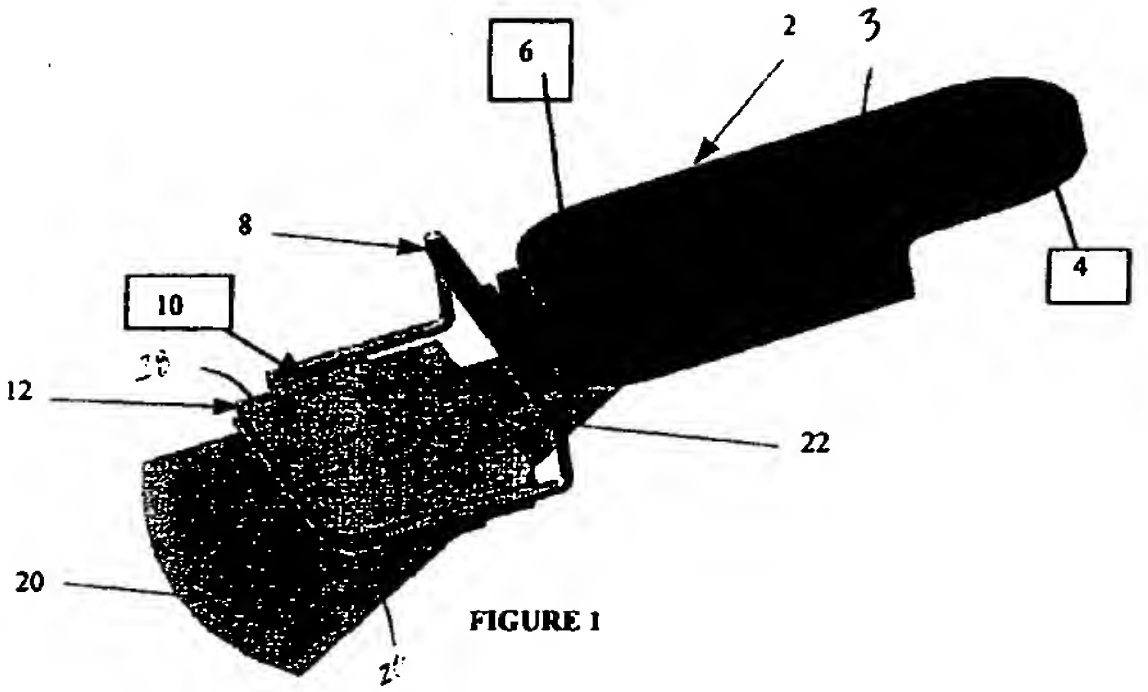


FIGURE 1

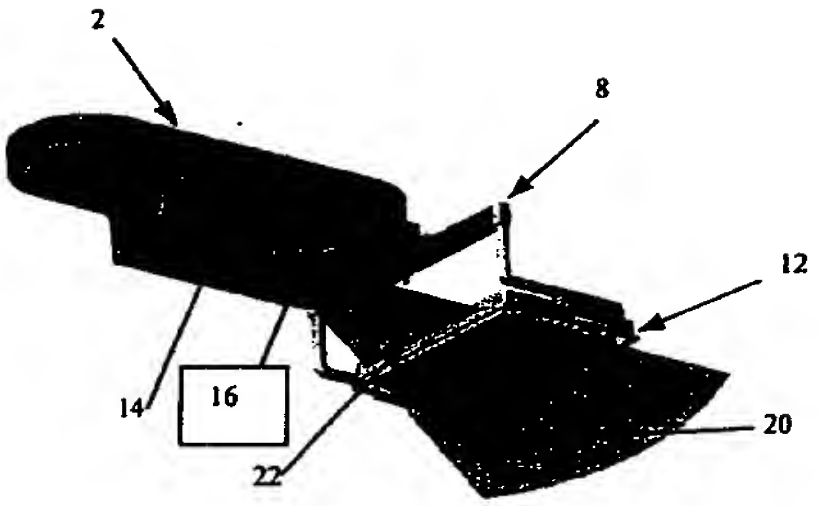


FIGURE 2

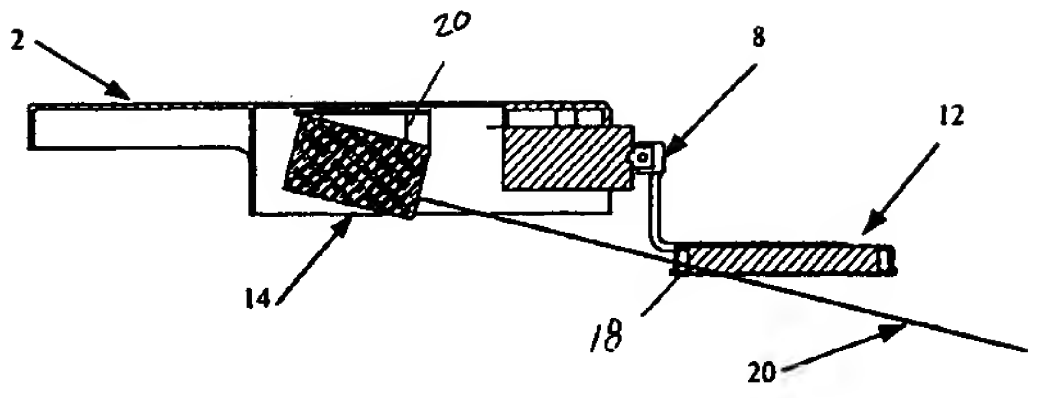


FIGURE 3

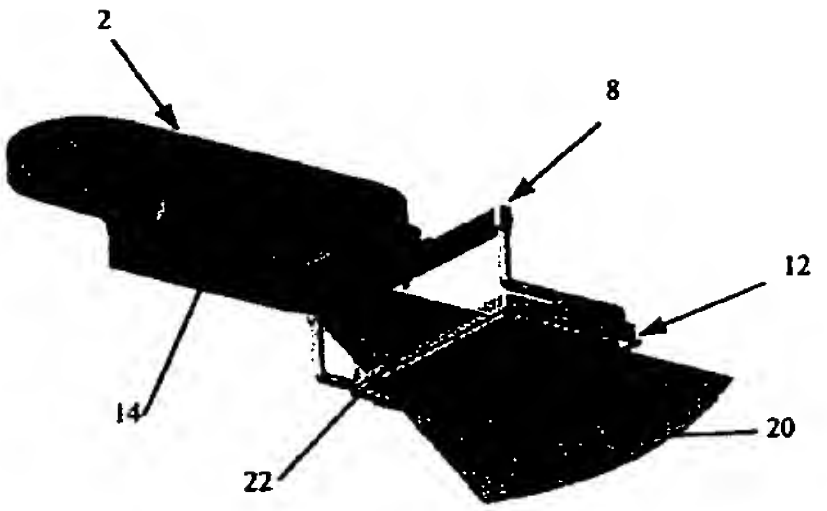


FIGURE 5

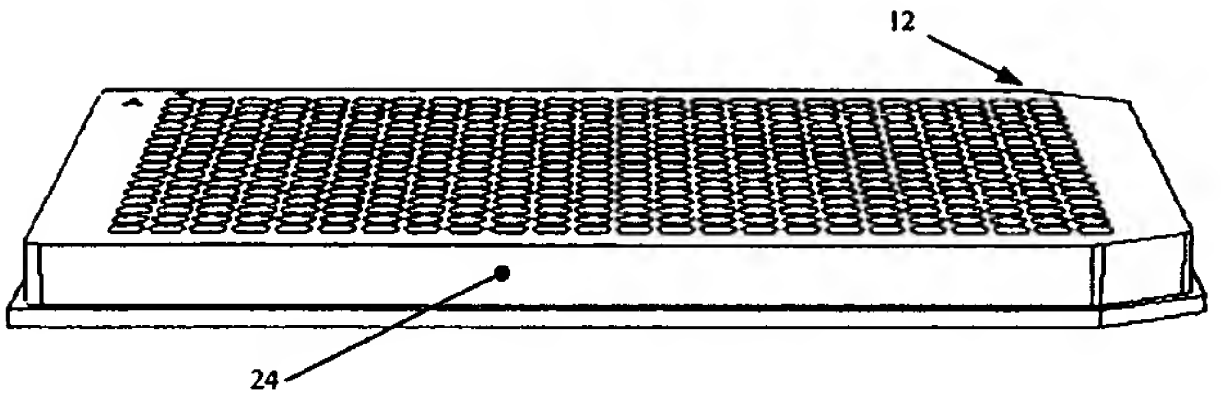


FIGURE 4

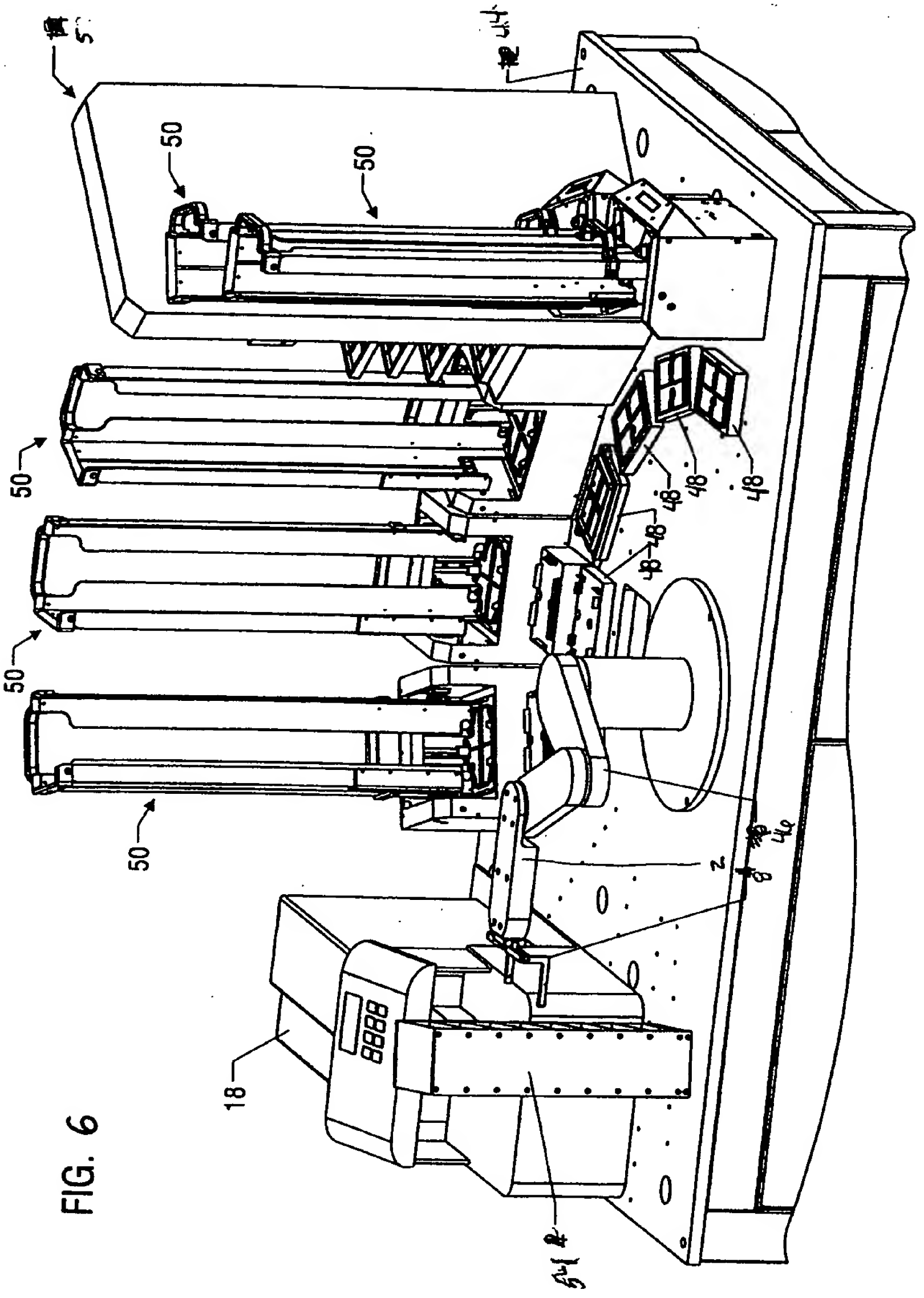


FIG. 6

INTERNATIONAL SEARCH REPORT

'ernational Application No
PCT/US 01/[redacted]14

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B25J19/02 G06K7/10 B01L3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B25J B01L G01N G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1999, no. 12, 29 October 1999 (1999-10-29) & JP 11 198068 A (SAMSUNG ELECTRON CO LTD), 27 July 1999 (1999-07-27) abstract & US 6 160 905 A (SAMSUNG ELECTRONICS CO LTD) 12 December 2000 (2000-12-12) abstract; figure 2 column 4, line 28 - line 52 column 5, line 57 - line 60	1,3,25, 31
Y		6,7, 10-12, 14,18, 20-22, 26-29

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
2 May 2001	11/05/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lumineau, S

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Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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